Natural Conditions Assessment for Low Dissolved Oxygen and Low pH, Beaverdam Creek and Tributaries in New Kent County, Virginia

Submitted by
Virginia Department of Environmental Quality

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Executive Summary

This report presents the assessment of whether low pH and dissolved oxygen (DO) in Beaverdam Creek and tributaries are due to natural conditions or whether a Total Maximum Daily Load (TMDL) must be performed because of anthropogenic impacts. Beaverdam Creek is located within New Kent County, Virginia, and is a major tributary of Diascund Reservoir, on Diascund Creek, which is a major tributary of the Chickahominy River, a major tributary of the James River. The waterbody identification (WBID) code for Beaverdam Creek is VAP-G09R. Beaverdam Creek encompasses a total of approximately 18.21 rivermiles (National Hydrography Dataset (NHD). Beaverdam Creek and tributaries were listed as impaired due to violations in water quality standards for DO and pH. This report addresses both the DO and pH impairments.

The total area of the Beaverdam Creek watershed is approximately 7.37 square miles. The average annual rainfall is 45 inches. The watershed is predominately forested (68 percent). Agriculture (cropland) comprises 1 percent of the watershed, with no significant pasture/hayland. Urban areas compose approximately 10 percent of the land base. The remaining 21 percent of the watershed is comprised of 12 percent other grasses and 9 percent wetlands. Land use was not considered to have significantly impacted the swampwater conditions of Beaverdam Creek and tributaries.

The mainstem of Beaverdam Creek downstream to Diascund Reservoir was listed as impaired on Virginia's 2002 303(d) Total Maximum Daily Load Priority List and Report, and the 2004, 2006, 2008, and 2010 305(b) / 303(d) Integrated Reports (VADEQ, 2002, 2004, 2006, 2008, and 2010) due to violations of the State's water quality standard for DO. This segment of Beaverdam Creek and unnamed tributary (UT) XAH were also listed as impaired for low pH and low DO respectively on Virginia's draft 2012 Integrated Report.

DEQ monitored 5 stations on Beaverdam Creek and UT XAH with dates ranging from August 1994 through January 2012. Two of five stations violated the pH water quality standard more than 10.5% of samples. Four of five stations, including the two that violated for pH, violated the DO water quality standard more than 10.5% of samples. Figures E1 and E2 show DO and pH concentrations at the listing station 2-BDM004.12 and at an upstream station 2-BDM004.60, respectively.

Figure E1. DO concentrations at Beaverdam Creek station 2-BDM004.12.

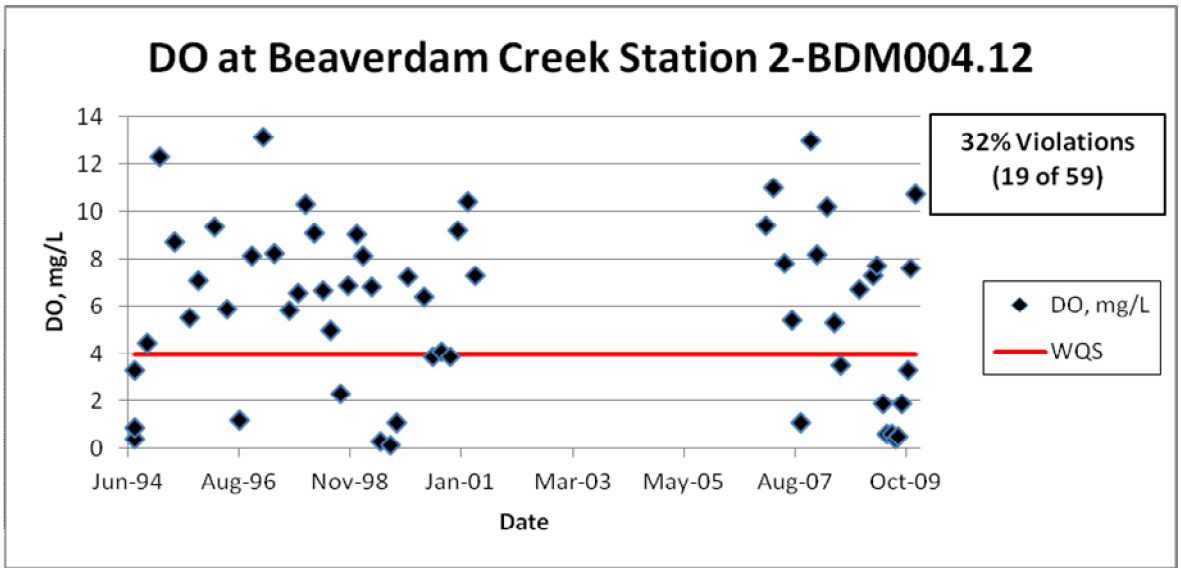
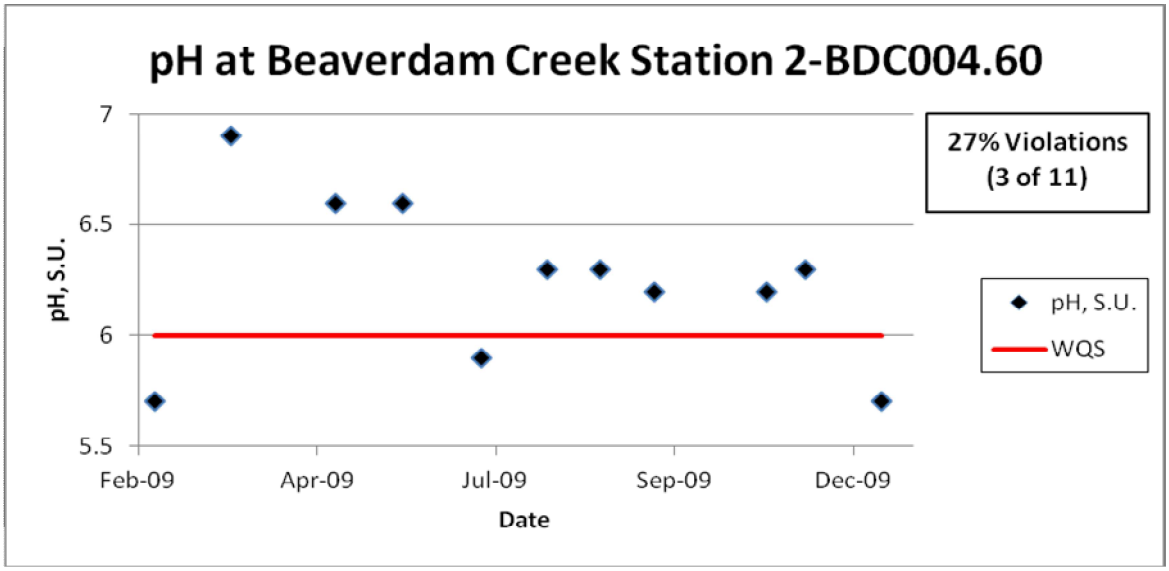


Figure E2. pH concentrations at Beaverdam Creek station 2-BDM004,60.



According to Virginia Water Quality Standards (9 VAC 25-260-10A), “all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish).”

As indicated above, Beaverdam Creek and tributaries must support all designated uses and meet all applicable criteria. If the waterbody violates the instantaneous DO water quality standard of 4.0 mg/l or pH values are less than 6.0 or greater than 9.0 in more than 10.5 percent of samples, the waterbody is classified as impaired and natural conditions must be determined or a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion.

In 2003 VADEQ proposed a methodology for determining whether low DO or pH originates from natural or anthropogenic sources, adapted from “Methodology for Assessing Natural Dissolved Oxygen and pH Impairments: Application to the Appomattox River Watershed, Virginia” (MapTech 2003).

The level of dissolved oxygen in a water body is determined by a balance between oxygen-depleting processes (*e.g.*, decomposition and respiration) and oxygen restoring processes (*e.g.*, aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. Conditions that would typically be associated with naturally low DO include slow-moving, ripple-less waters where the bacterial decay of organic matter depletes DO at a faster rate than it can be replenished. Indicators of these conditions include low slope, the presence of swamps or wetlands. These conditions often also produce low pH due to organic acids (tannins, humic and fulvic substances) produced in the decay process. These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems.

The general approach to determine if DO and pH impairments in free-flowing streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or low pH levels and for determining the likelihood of anthropogenic impacts is described below. DEQ staff use this approach to implement State Water Control Law 9 VAC 25-260-55, Implementation Procedure for Dissolved Oxygen Criteria in Waters Naturally Low in Dissolved Oxygen.

Before implementing this procedure, all DO and pH data should be screened for flows less than the 7Q10. DO and pH data collected on days when flow was < 7Q10 should be eliminated from the data set and the violation rate recalculated accordingly.

Step 1. Determine slope and appearance (presence of wetlands).
Step 2. Determine nutrient levels and compare with USGS background concentrations.
Step 3. Determine degree of seasonal fluctuation (for DO only).
Step 4. Determine anthropogenic impacts from permitted dischargers and land use.

No Beaverdam Creek and tributaries DO or pH water quality data, standard violations or non-violations were obtained at flows below 7Q10, therefore no data were removed.

The percent slope of Beaverdam Creek and tributaries ranged from 0.17% to 0.26% slope. This is lower than the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swamps and heavy tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic impacts.

The VADEQ collected nutrient data from the original listing station 2-BDM004.12. The average nitrate and total nitrogen concentrations are below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas with levels of nitrate < 0.6 mg/l and TN < 1.0 mg/l. These low nutrient levels are not indicative of human impact. The average total phosphorus (TP) mg/l was moderately higher (28% higher) than the USGS (1999) background TP value of 0.1 mg/l. The nitrogen levels were all low, however both TP and orthophosphate (o-P) the somewhat higher than normal background levels.

There are no permitted dischargers in the Beaverdam Creek watershed. However there is an unpermitted mulch facility upstream of station 2-BDM004.60 and below 2-BDM005.70. Because of the elevated TP at the listing station, DEQ monitored nutrients at the 3 other stations in 2009. The TP levels at station 2-BDM004.60 between the listing station and the mulch facility were 89% above the USGS background, and were higher than at the listing station, however there is another unmonitored UT also entering Beaverdam Creek between this station and the mulch facility. Station 2-BDM005.70 is upstream of the mulch facility and the other unmonitored UT to Beaverdam Creek. The TP at this site barely exceeded (3% higher) the background TP level, and is significantly (42%) lower than the station downstream. Station 2CXAH000.35 is on a UT that enters Beaverdam Creek downstream of both the mulch facility and TP-elevated station 2-BDM004.60, and upstream of the original station 2-BDM004.12. The TP at this site was also just over (9% higher) the TP background level and is similar to TP at the upstream background Beaverdam Creek station 2-BDM005.70. The lower TP concentration at this UT station seemed to dilute those from station 2-BDM004.60 at Rt. 30.

It is unusual that only TP levels were elevated in this watershed while nitrogen species were not high. This would seem to point to a natural source of TP, perhaps in the geology, rather than a point source such as a mulch facility or agriculture, which would also contribute excess nitrogen. There are no acres of pasture and only a very small acreage of cropland in the watershed, so agricultural runoff is not a likely source of the elevated TP either. Nevertheless, with the elevated TP, Beaverdam Creek should not be designated Class VII swampwaters as the nutrient criteria for designation exist now.

Beaverdam Creek exhibits natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO.

There are no active permitted point source dischargers in the Beaverdam Creek watershed. However there is an unpermitted mulch facility upstream of station 2-BDM004.60 and below 2-BDM005.70. DEQ will seek permission to sample for nutrients immediately above and below this facility to determine whether it is a source of elevated TP, then proceed accordingly.

Based on the above information, a change in the water quality standards classification to Class VII Swampwater due to natural conditions, rather than a TMDL, is not indicated for Beaverdam Creek and tributaries located in waterbody identification codes (WBID) VAP-G09R because the TP concentrations at the four monitoring stations were from 3% and 89% higher than the nutrient concentrations deemed by the USGS to indicate background nutrient levels. Beaverdam Creek in VAP-G09R will receive a non-point source (NPS) load allocation for TP and TN in the approved Chesapeake Bay TMDL. This will obviate the need for future nutrient-based DO and pH TMDLs for the watershed.

Even though TP is elevated above the USGS background levels, Beaverdam Creek, or any potential swampwater designee, is still a swamp, with naturally low pH and/or DO, albeit one with slightly to moderately elevated TP. As long as slope percentage is below 0.50%, swampwater characteristics are present, and anthropogenic point sources are not present which contribute acidic effluents to lower pH or high BOD effluents to lower DO, a swamp will still naturally have low dissolved oxygen and low pH. NPS TP or TN rarely if ever cause low DO or pH problems by themselves because the nutrient concentrations are not high enough, absent a point source of biochemical or chemical oxygen demand or a rare illicit dumping of concentrated TN source like fertilizer. The effect of a Class VII designation is to lower the pH and DO water quality standards to pH 4.3 and to a narrative low DO standard, so that natural swampwaters with low DO and pH do not require an unnecessary Total Maximum Daily Load clean-up study where no anthropogenic problem exists. This lower DO and pH standards relief is needed and appropriate for a natural swamp segment without man-made impacts whether elevated nutrient species are present or not.

DEQ performed the assessment of the Beaverdam Creek and tributaries low DO and low pH natural condition in lieu of a TMDL. Therefore neither a TMDL Technical Advisory Committee (TAC) meeting nor a public meeting was involved. Public participation will occur during the next water quality standards triennial review process.

1. Introduction

Beaverdam Creek is located within New Kent County, Virginia, and is a major tributary of Diascund Reservoir on Diascund Creek, a major tributary of the Chickahominy River, which is a major tributary of the James River. There are 18.21 total stream miles in the Beaverdam Creek watershed (National Hydrography Dataset (NHD)) using GIS. Beaverdam Creek is fed by several unnamed tributaries (UT), the largest of which is UT XAH. The impaired segment for low dissolved oxygen (DO) totals 6.58 miles of Beaverdam Creek and UT XHA. The impaired segment for low pH totals 4.35 miles, the entire length of mainstem Beaverdam Creek. The low pH segment mileage is duplicated within the low DO segment mileage. Beaverdam Creek and tributaries generally flow south from the headwaters near Slaterville, VA, to the backwater of Diascund Reservoir. The lower 2.60 miles of Beaverdam Creek are backwatered by this reservoir.

2. Physical Settings

2.1. Listed Water Bodies

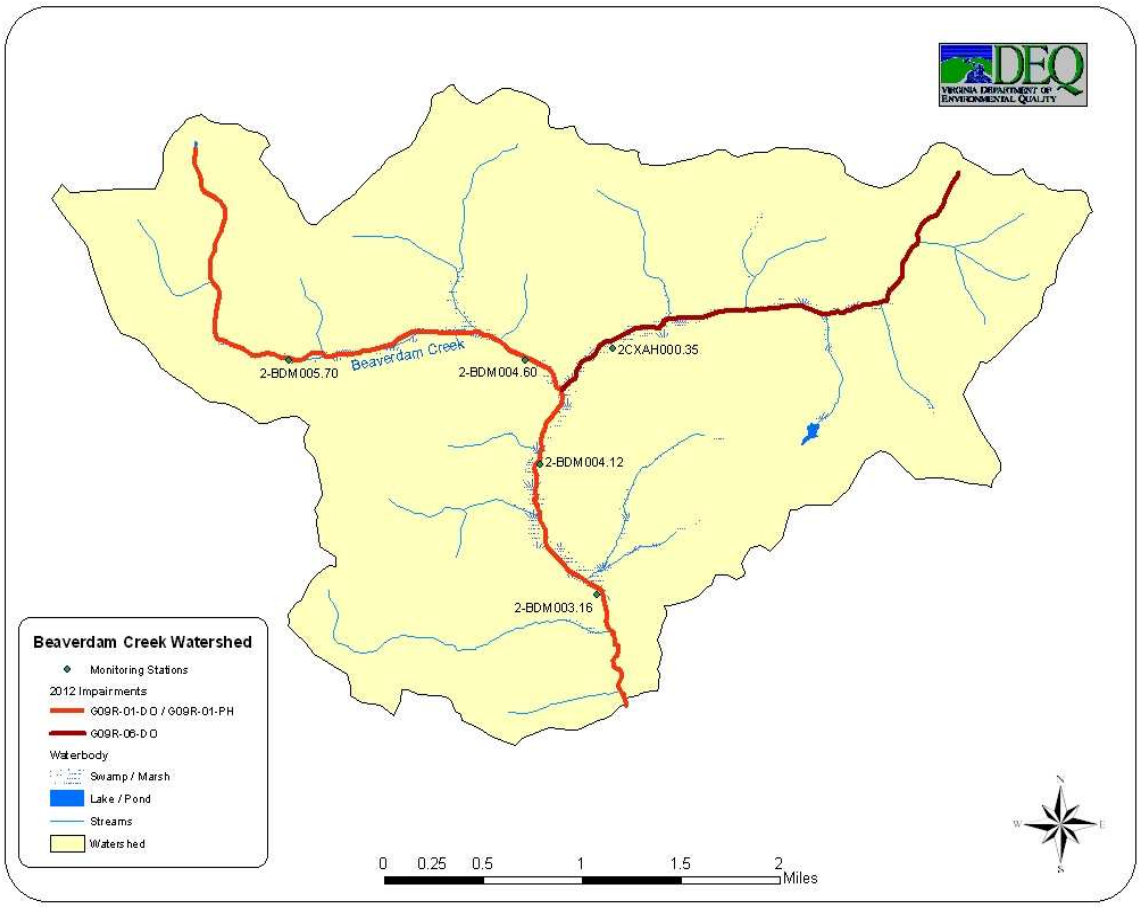
The mainstem of Beaverdam Creek downstream to Diascund Reservoir was listed as impaired on Virginia's 2002 303(d) Total Maximum Daily Load Priority List and Report, and the 2004, 2006, 2008, and 2010 305(b) / 303(d) Integrated Reports (VADEQ, 2002, 2004, 2006, 2008, and 2010) due to violations of the State's water quality standard for DO. This segment of Beaverdam Creek and UT XAH were also listed as impaired for low pH and low DO respectively on Virginia's draft 2012 Integrated Report. This report evaluates both the DO and pH impairments by determining if natural conditions are the cause of the impairment, thus obviating the need for a TMDL. The waterbody identification code (WBID, Virginia Hydrologic Unit) for non-tidal Beaverdam Creek is VAP-G09R.

2.2. Watershed

2.2.1. General Description

Beaverdam Creek and tributaries generally flow south from the headwaters near Slaterville, VA, to the Diascund Creek Reservoir. The watershed totals approximately 7.37 mi^2. There is no continuous flow gaging station on Beaverdam Creek or tributaries. See Figure 1 for a map of the watershed including 5 monitoring stations.

Figure 1. The Beaverdam Creek watershed map and associated monitoring stations.



2.2.2. Geology, Climate, Land Use

Geology and Soils

The impaired segment of Beaverdam Creek is within the Atlantic Coastal Plain physiographic region. The Atlantic Coastal Plain is the easternmost of Virginia's physiographic provinces. The Atlantic Coastal Plain extends from New Jersey to Florida, and includes all of Virginia east of the Fall Line. The Fall Line is the easternmost extent of rocky river rapids, the point at which east-flowing rivers cross from the hard, igneous and metamorphic rocks of the Piedmont to the relatively soft, unconsolidated strata of the Coastal Plain. The Coastal Plain is underlain by layers of Cretaceous and younger clay, sand, and gravel that dip gently eastward. These layers were deposited by rivers carrying sediment from the eroding Appalachian Mountains to the west. As the sea level rose and fell, fossiliferous marine deposits were interlayered with fluvial, estuarine, and beach strata. The youngest deposits of the Coastal Plain are sand, silt and mud presently being deposited in our bays and along our beaches (http://www.dcr.virginia.gov/natural_heritage/documents/overviewPhysiography_vegetation.pdf).

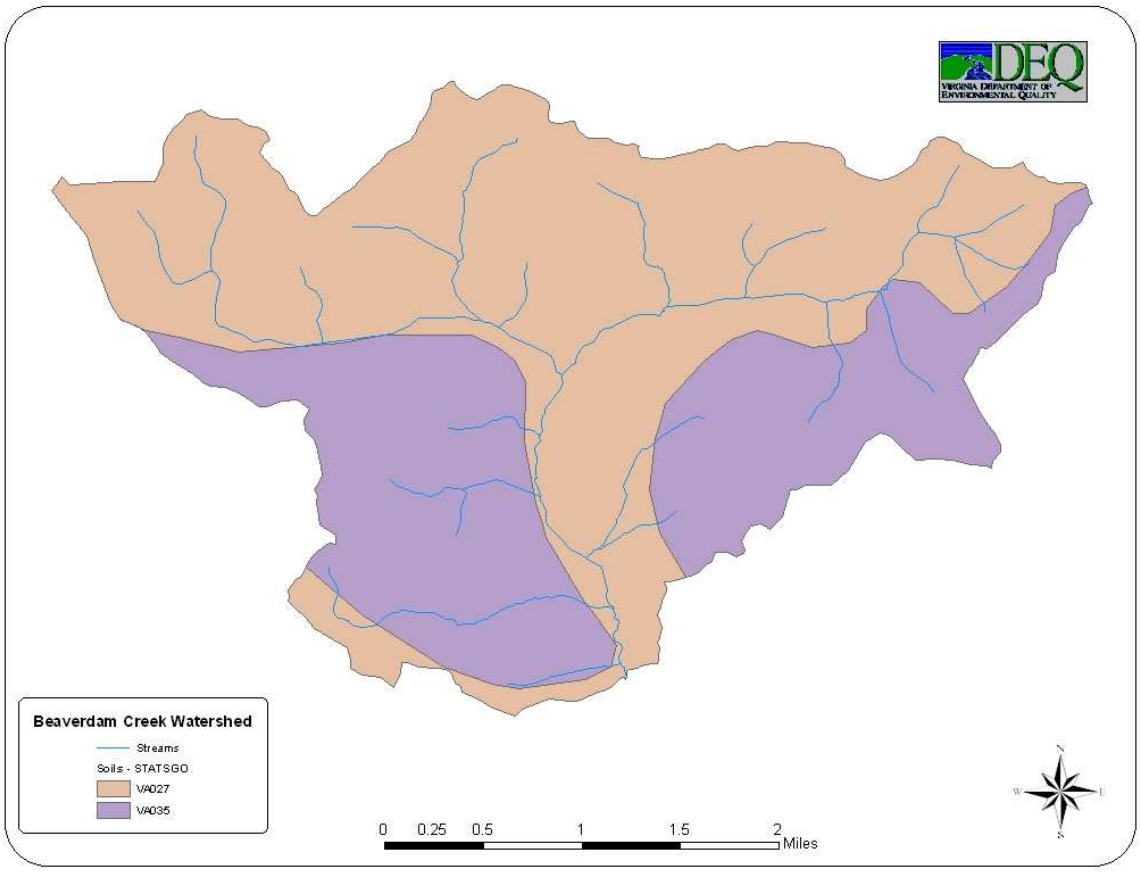
Soils for the Beaverdam Creek watershed were documented utilizing the VA State Soil Geographic Database (STATSGO). Three general soil types were identified using in this database. Descriptions of these soil series were derived from queries to the USDA Natural Resources Conservation Service (NRCS) Official Soil Series Description web site (http://soils.usda.gov/technical/classification/osd/index.html). Figure 2 shows the location of these general soil types in the watershed.

Soils of the Emporia-Johnston-Kenansville-Remlik-Rumford-Slagle-Suffolk-Tomotley (VA027) series are very deep to deep, and vary between well drained to poorly drained with moderately slow or slow permeability.

They formed in moderately fine-textured stratified fluvial and marine sediments on the upper Coastal Plain and stream terraces.

The soils of the Craven-Mattaponi-Lenoir-Coxville (VA035) series are very deep in which the drainage ranges from somewhat poor to well drained and the permeability is typically slow to moderately slow. The soils formed in flats or depressions from the lower to upper Coastal Plain and Piedmont Physiographic Provinces of the Atlantic Coast, in which the parent materials consists of fluvial and marine sediments.

Figure 2. Soil Characteristics of the Beaverdam Creek Watershed.



Climate

The climate summary for Beaverdam Creek comes from a weather station located in West Point, VA (449025) with a period of record from 1954 to 2010. The average annual maximum and minimum temperatures (°F) at the weather station are 69.8 and 47.0 and the annual rainfall (inches) is 45.30 (Table 1) (Southeast Regional Climate Center, http://www.sercc.com/climateinfo/historical/historical_va.html).

Table 1. Climate summary for West Point, Virginia (449025).

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	47.8	51.1	60.3	71.3	78.7	85.9	89.3	87.7	81.7	71.3	61.6	51.1	69.8
Average Min. Temperature (F)	27.3	29.1	36.0	45.1	54.3	62.8	67.0	66.0	59.2	47.7	38.7	30.4	47.0

Average Total Precipitation (in.)	3.48	3.12	4.01	3.26	3.91	3.82	4.85	4.66	4.19	3.47	3.21	3.35	45.30

Land Use

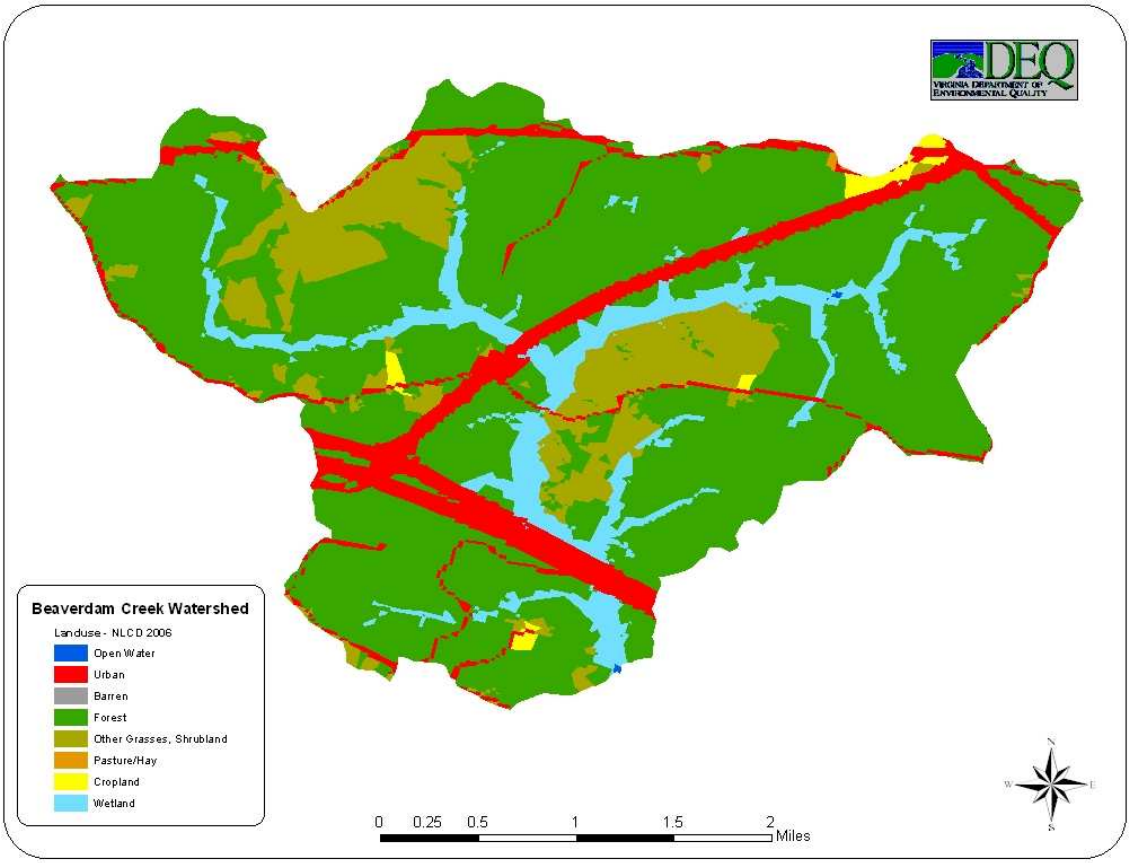
The Beaverdam Creek free-flowing watershed extends from approximately Slaterville, VA, to the backwater of Diascund Reservoir. It is approximately 9 miles long and 2.5 miles wide. The watershed is approximately 4723 acres (7.37 mi^2) in size and is predominately forested (68 percent). Agriculture (cropland) comprises 1 percent of the watershed, with no significant pasture/hayland. Urban areas compose approximately 10 percent of the land base. The remaining 21 percent of the watershed is comprised of 12 percent other grasses and 9 percent wetlands. Land use is described in Table 2.

A map of the distribution of land use in the watershed (Figure 3) shows that urban land use is concentrated at the major roads the lower third and center of the watershed along I-64, Rt. 30 and the remaining county roads. Wetlands are concentrated along the mainstems of Beaverdam Creek and UT XAH.

Table 2. Land Use in the Beaverdam Creek Watershed

Land Use Type	Acres	Square Miles	Percent
Open Water	0	0	0.0%
Urban	486	0.76	10.3%
Barren	0	0	0.0%
Forest	3219	5.03	68.2%
Pasture/Hay	0	0	0.0%
Cropland	38	0.06	0.8%
Other Grasses	570	0.89	12.1%
Wetland	403	0.63	8.6%
Totals:	**4716**	**7.37**	**100%**
Land Use Type	**Acres**	**Square Miles**	**Percent**

Figure 3. Land Use in the Beaverdam Creek Watershed



3. Description of Water Quality Problem/Impairment

The mainstem of Beaverdam Creek downstream to Diascund Reservoir was listed as impaired on Virginia's 2002 303(d) Total Maximum Daily Load Priority List and Report, and the 2004, 2006, 2008, and 2010 305(b) / 303(d) Integrated Reports (VADEQ, 2002, 2004, 2006, 2008, and 2010) due to violations of the State's water quality standard for DO. This segment of Beaverdam Creek and UT XAH were also listed as impaired for low pH and low DO respectively on Virginia's draft 2012 Integrated Report. This report evaluates both the DO and pH impairments by determining if natural conditions are the cause of the impairment, thus obviating the need for a TMDL.

DEQ monitored 5 stations on Beaverdam Creek and UT XAH (see Figure 1) with dates ranging from August 1994 through January 2012. Of the 99 total pH data points recorded, 9 violated water quality standards for pH (9%), and 32 of 100 DO data points violated the water quality standards for DO concentration (32%). The pH minimum and maximum values ranged from 5.4 to 7.3 S.U., and DO values ranged from 0.2 to 13.13 mg/L. Two of five stations violated the pH water quality standard more than 10.5% of samples. Four of five stations, including the two that violated for pH, violated the DO water quality standard more than 10.5% of samples. The results are summarized in Table 3.

Table 3. pH and DO data collected by DEQ from 5 stations on Beaverdam Creek and UT XAH.

		Number of Samples		SU		mg/l		Number of Violations	
Station	Sample Period	pH	DO	Average pH	Min-Max pH	Average DO	Min-Max DO	pH	DO

2-BDM004.12	8/3/1994 to 1/17/2012	58	59	6.58	5.6 – 7.04	6.00	0.14 – 13.13	2	19
2-BDM003.16	2/16/2009 to 12/14/2009	11	11	6.56	5.8 – 7.0	6.48	2.8 - 11.1	2	2
2-BDM004.60	2/12/2009 to 12/14/2009	11	11	6.25	5.7 – 6.9	2.89	0.2- – 8.6	3	7
2-BDM005.70	2/16/2009 to 12/14/2009	11	11	6.68	5.4 – 7.3	7.08	5.3 – 10.1	1	0
2CXAH000.35	2/12/2009 to 12/14/2009	8	8	6.48	5.9 – 7.0	5.19	0.3 – 9.4	1	4

Time series graphs of all DO and pH data collected at the original listing station, Beaverdam Creek at station 2-BDM004.12, shows the DO ranged from 0.14 to 13.13 mg/L and the pH ranging from 5.6 to 7.04 S.U. (Figure 4) and (Figure 5). The horizontal red line at the DO = 4.0 mark represents the minimum water quality standard in Figure 4. The data points below the DO = 4.0 line are violations of the water quality standard in Figure 4. The horizontal red line at the pH = 6.0 mark represents the minimum water quality standard in Figure 5. The data points below the pH = 6.0 line are violations of the water quality standard in Figure 5.

Figure 4. Time series of DO at **Beaverdam Creek station 2-BDM004.12, omitting 1/17/2012 DO = 10.73.**

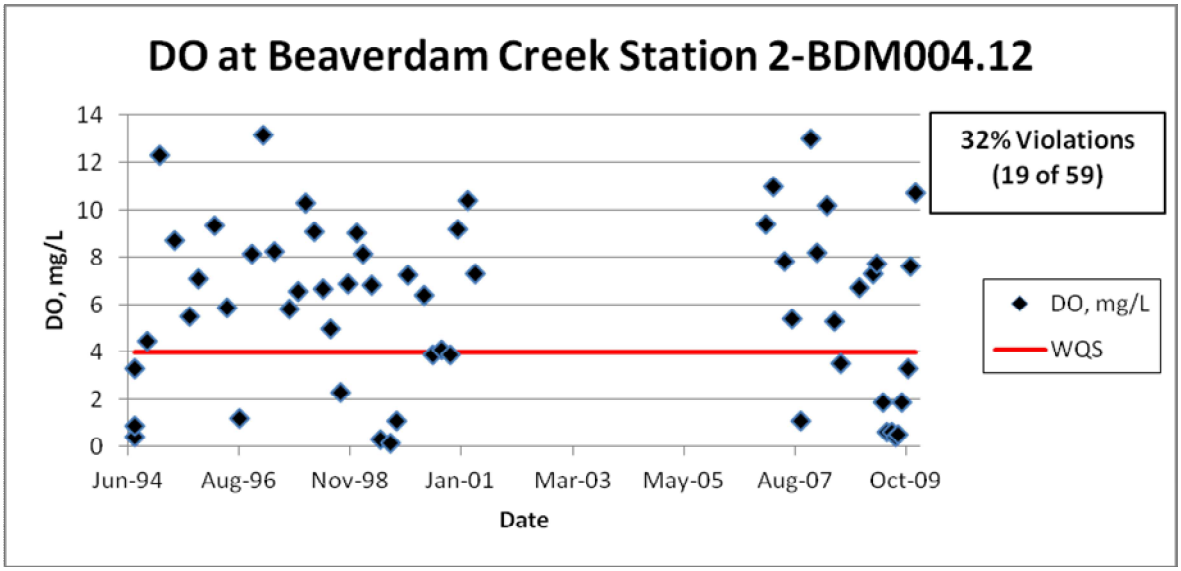
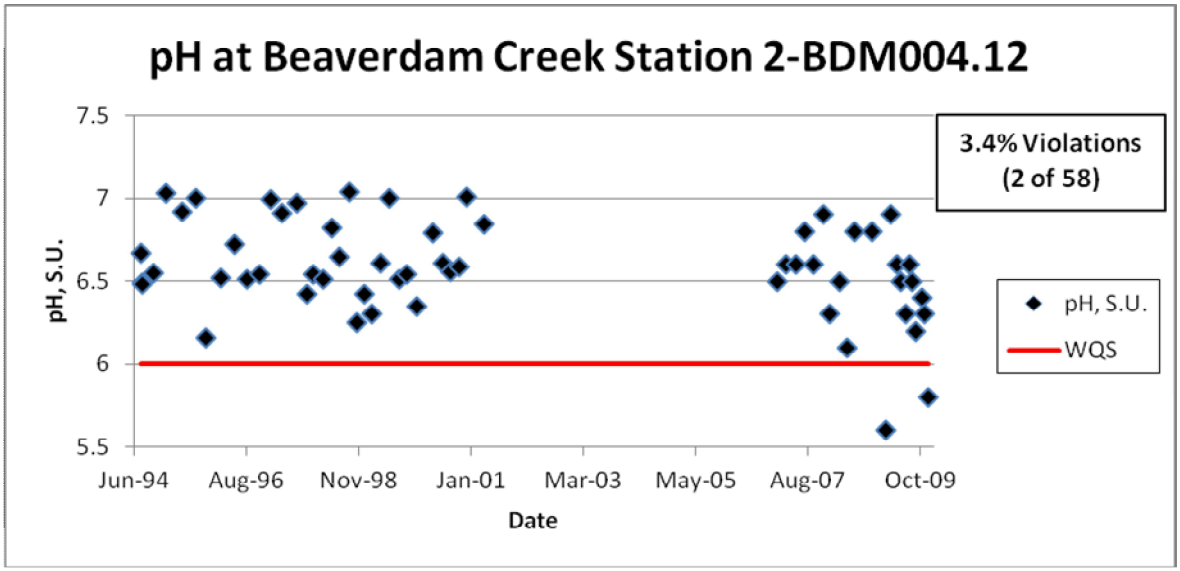


Figure 5. Time series of pH at **Beaverdam Creek station 2-BDM004.12, omitting 1/17/2012 pH = 6.77.**



3.1. Associated pH and DO of Beaverdam Creek and Tributaries

DEQ also monitored DO and pH data at four other stations on Beaverdam Creek and a UT for the assessment of low DO and pH due to the natural conditions. Two of three associated stations exceeded the water quality standards for DO and pH in more than 10.5 percent of visits. The most upstream station on Beaverdam Creek, 8-BDM005.70 exceeded neither the DO nor pH standards in more than 10 percent of visits. See Figures 6 through 13 for time series of DO and pH at associated Beaverdam Creek and UT stations.

Figure 6. Time series of DO at Beaverdam Creek station 2-BDM004.60, minus June 1995 pH of 6.03 S.U.

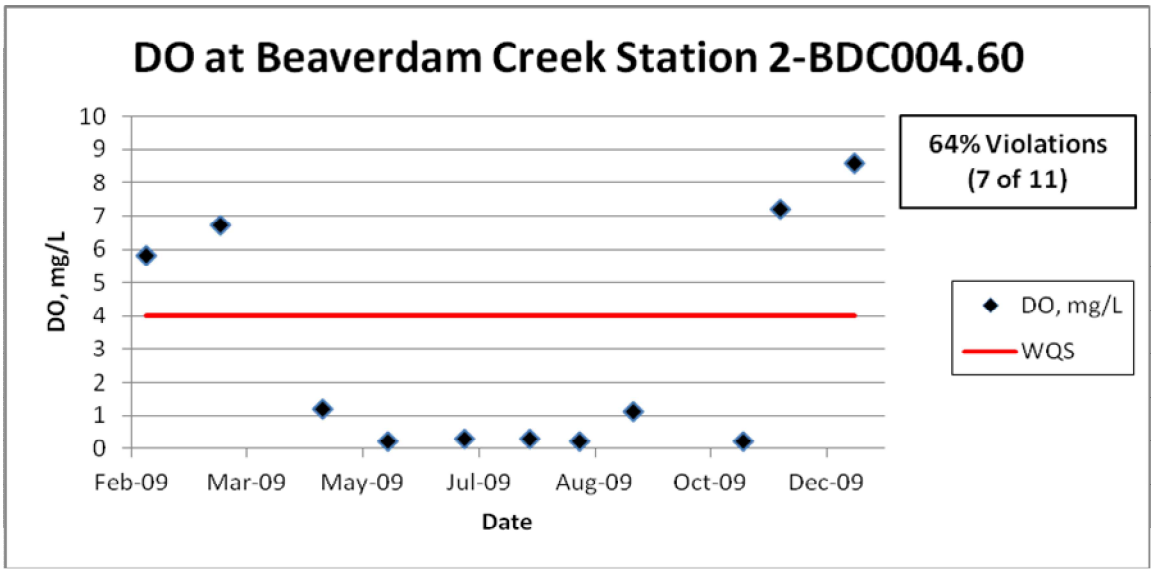


Figure 7. Time series of pH at **Beaverdam Creek station 2-BDM004.60.**

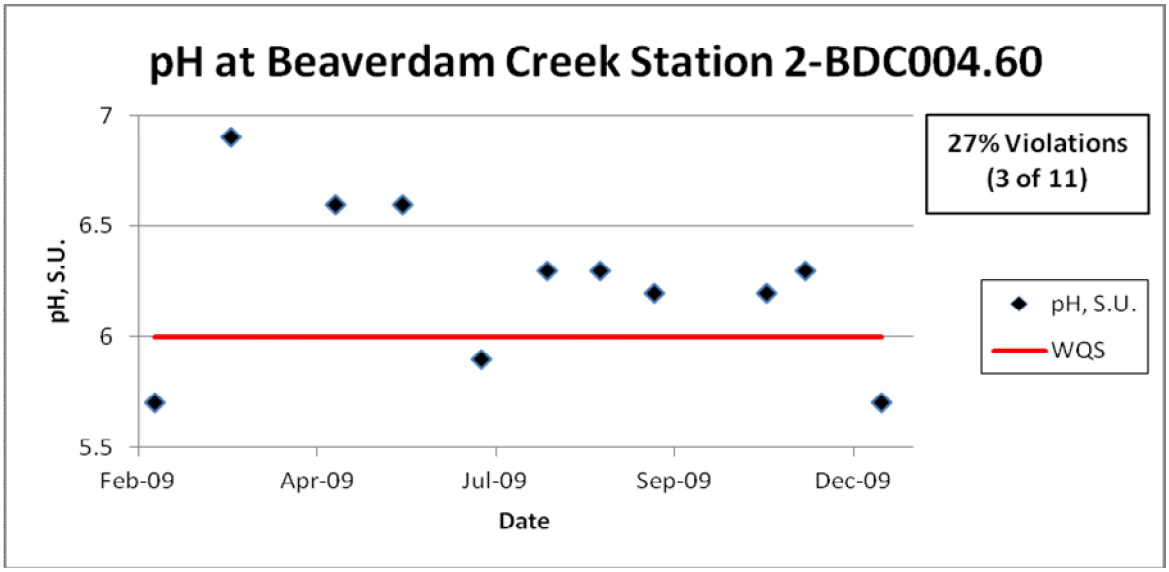


Figure 8. Time series of DO at **Beaverdam Creek station 2-BDM005.70.**

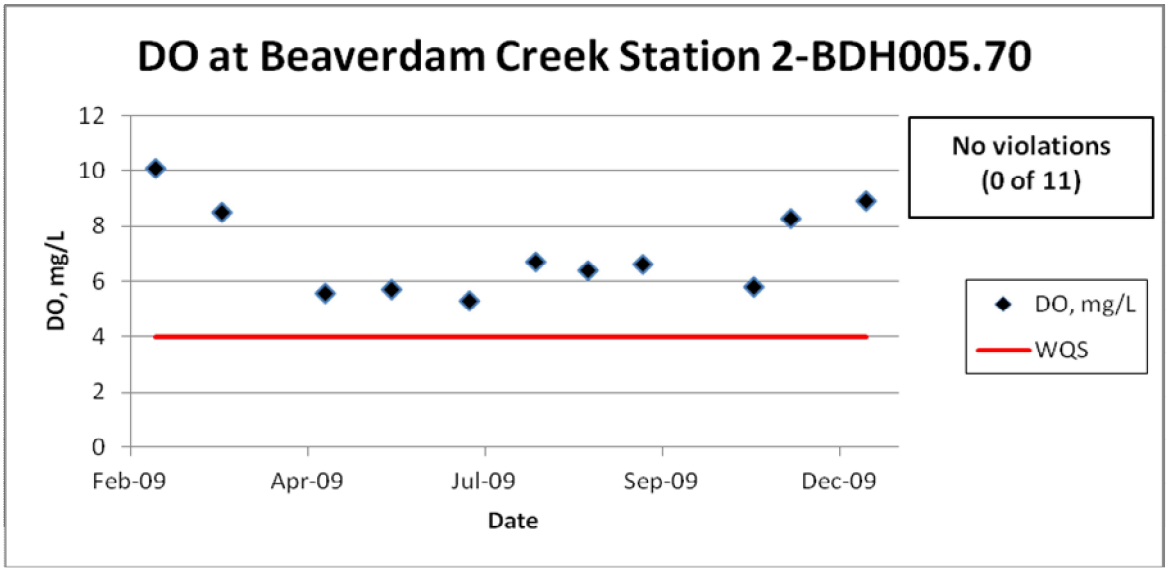


Figure 9. Time series of pH at Beaverdam Creek station 2-BDM005.70.

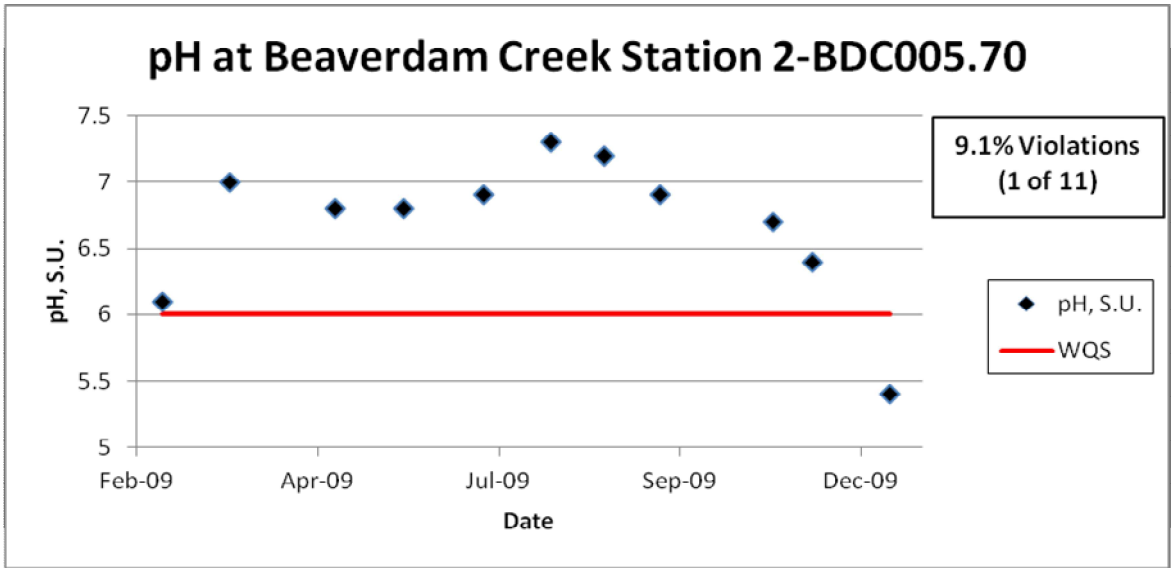


Figure 10. Time series of DO at UT Beaverdam Creek station 2CXAH000.35, minus 1/25/12 9.32 mg/L.

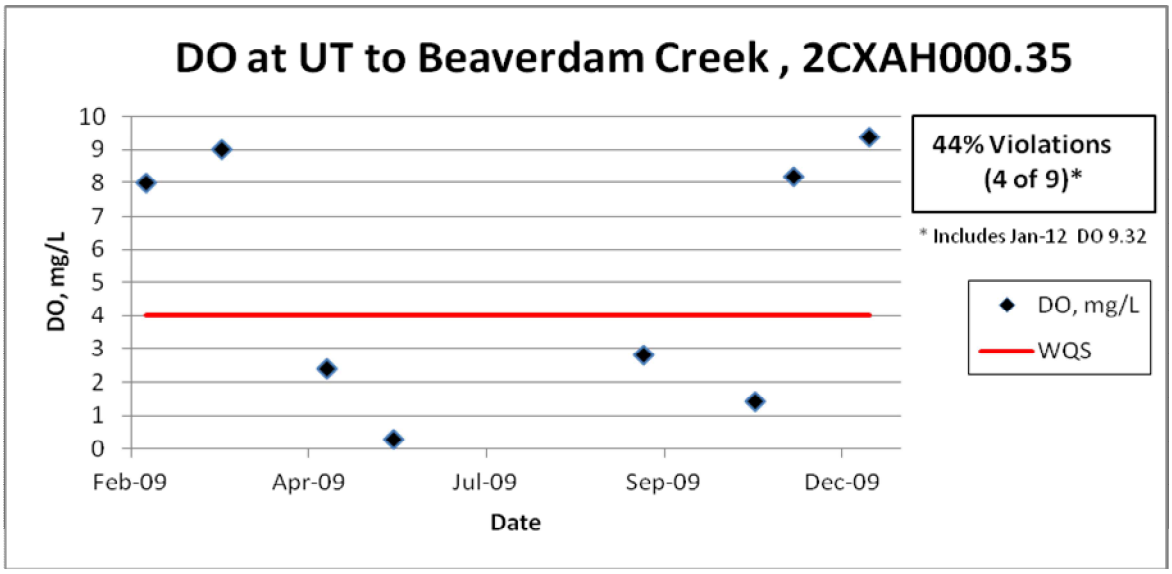


Figure 11. Time series of pH at UT Beaverdam Creek station 2CXAH000.35, minus 1/25/12 pH 6.52 S.U.

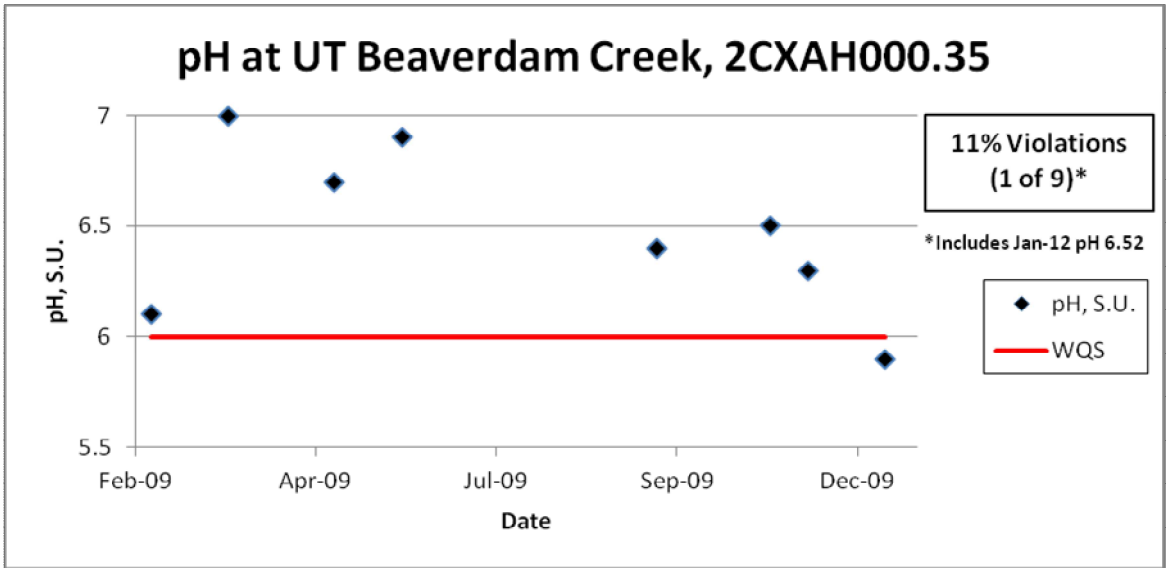


Figure 12. Time series of DO at Beaverdam Creek station 2-BDM003.16.

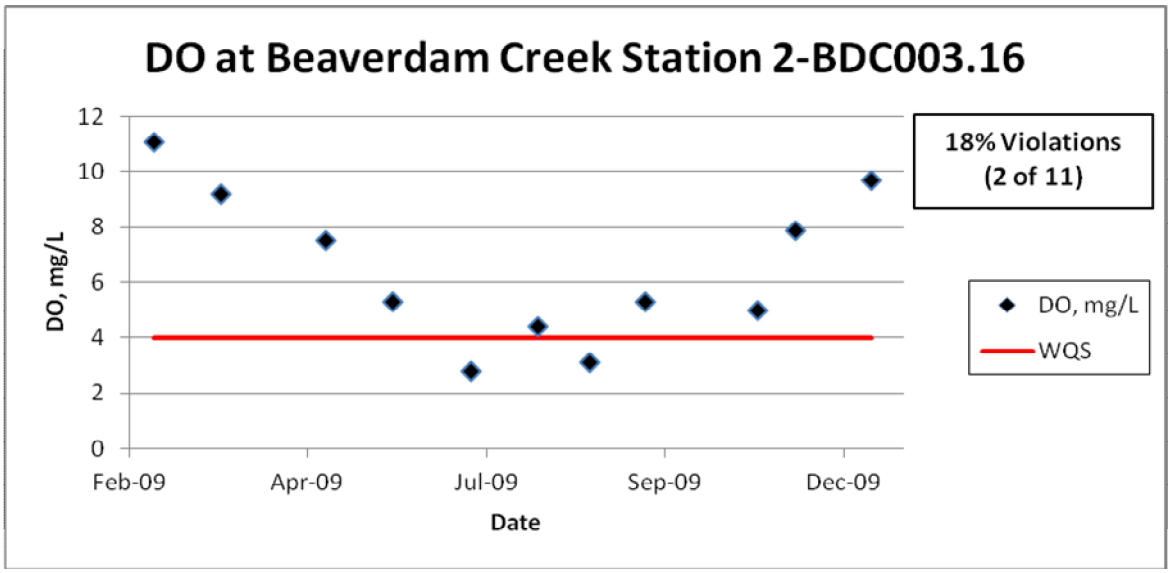
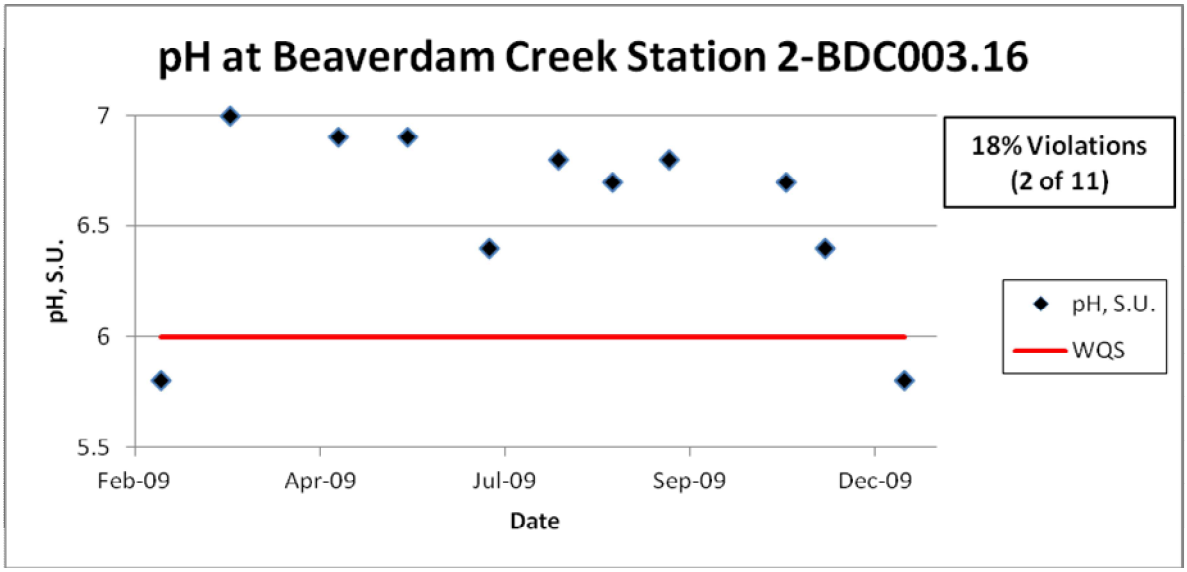


Figure 13. Time series of pH at Beaverdam Creek station 2-BDM003.16.



4. Water Quality Standard

According to Virginia Water Quality Standards (9 VAC 25-260-5), the term *"water quality standards means provisions of state or federal law which consist of a designated use or uses for the waters of the Commonwealth and water quality criteria for such waters based upon such uses. Water quality standards are to protect the public health or welfare, enhance the quality of water and serve the purposes of the State Water Control Law (§62.1-44.2 et seq. of the Code of Virginia) and the federal Clean Water Act (33 USC §1251 et seq.)."*

As stated above, Virginia water quality standards consist of a designated use or uses and water quality criteria. These two parts of the applicable water quality standard are presented in the sections that follow.

4.1. Designated Uses

According to Virginia Water Quality Standards (9 VAC 25-260-10A), *"all state waters are designated for the following uses: recreational uses (e.g., swimming and boating); the propagation and growth of a balanced indigenous population of aquatic life, including game fish, which might be reasonably expected to inhabit them; wildlife; and the production of edible and marketable natural resources (e.g., fish and shellfish)."*

As stated above, Beaverdam Creek must support all designated uses and meet all applicable criteria.

4.2. Applicable Water Quality Criteria

The applicable water quality criteria for DO and pH in the Beaverdam Creek watershed are an instantaneous minimum DO of 4.0 mg/l and pH from 6.0 SU to 9.0 SU, as in Table 4.

Table 4. Applicable water quality standards

Parameter	Minimum, mg/l	Maximum, mg/l
pH	6.0	9.0
DO	4.0	-

If the waterbody exceeds the criterion listed above in more than 10.5 percent of samples, the waterbody is classified as impaired and natural conditions must be determined or a TMDL must be developed and implemented to bring the waterbody into compliance with the water quality criterion.

5. Assessment of Natural Conditions Affecting low DO - Process for determining if DO and pH impairments in free-flowing streams are due to natural conditions.

The level of dissolved oxygen in a water body is determined by a balance between oxygen-depleting processes (*e.g.*, decomposition and respiration) and oxygen-restoring processes (*e.g.*, aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen- depleting processes. The level of pH in a water body is determined by a balance between organic acids produced by decay of vegetative material, and buffering capacity. Conditions in a stream that would typically be associated with naturally low DO and pH include slow-moving, ripple-less waters or wetlands where the decay of organic matter produces organic acids. These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems. The general approach to determine if DO and pH impairments in streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or pH levels and for determining the likelihood of anthropogenic impacts that will exacerbate the natural condition is described below.

Step 1. Determine slope and appearance.
Step 2. Determine nutrient levels.
Step 3. Determine degree of seasonal fluctuation (for DO only).
Step 4. Determine anthropogenic impacts.

The results from this methodology (or process or approach) will be used to determine if the stream should be re-classified as Class VII Swamp Waters. Each step is described in detail below.

Procedure for Natural Condition Assessment of low pH and low DO in Virginia Streams

Prepared by Virginia Department of Environmental Quality
October 2004

I. INTRODUCTION

Virginia's list of impaired waters currently shows many waters not supporting the aquatic life use due to exceedances of pH and/or DO criteria that are designed to protect aquatic life in Class III waters. However, there is reason to believe that most of these streams or

stream segments have been mis-classified and should more appropriately be classified as Class VII, Swamp Waters. This document presents a procedure for assessing if natural conditions are the cause of the low pH and/or low DO levels in a given stream or stream segment.

The level of dissolved oxygen (DO) in a water body is determined by a balance between oxygen-depleting processes (*e.g.*, decomposition and respiration) and oxygen-restoring processes (*e.g.*, aeration and photosynthesis). Certain natural conditions promote a situation where oxygen-restoring processes are not sufficient to overcome the oxygen-depleting processes. The level of acidity as registered by pH in a water body is determined by a balance between organic acids produced by decay of vegetative material, and buffering capacity.

Conditions in a stream that would typically be associated with naturally low DO and/or naturally low pH include slow-moving, ripple-less waters. In such waters, the decay of organic matter depletes DO at a faster rate than it can be replenished and produces organic acids (tannins, humic and fulvic substances). These situations can be compounded by anthropogenic activities that contribute excessive nutrients or readily available organic matter to these systems.

The general approach to determine if DO and pH impairments in streams are due to natural conditions is to assess a series of water quality and hydrologic criteria to determine the likelihood of an anthropogenic source. A logical 4-step process for identifying natural conditions that result in low DO and/or pH levels and for determining the likelihood of anthropogenic impacts that will exacerbate the natural condition is described below. DEQ staff is proposing to use this approach to implement State Water Control Law 9 VAC 25-260-55, Implementation Procedure for Dissolved Oxygen Criteria in Waters Naturally Low in Dissolved Oxygen.

Waters that are shown to have naturally low DO and pH levels will be re-classified as Class VII, Swamp Waters, with the associated pH criterion of 4.3 to 9.0 SU. An associated DO criterion is currently being developed from swamp water data. A TMDL is not needed for these waters. An assessment category of 4C will be assigned until the waterbody has been re-classified.

II. NATURAL CONDITION ASSESSMENT

Following a description of the watershed (including geology, soils, climate, and land use), a description of the DO and/or pH water quality problem (including a data summary, time series and monthly data distributions), and a description of the water quality criteria that were the basis for the impairment determination, the available information should be evaluated in four steps.

Step 1. Determine appearance and flow/slope.

Streams or stream segments that have naturally low DO (< 4 mg/L) and low pH (< 6 SU) are characterized by very low slopes and low velocity flows (flat water with low reaeration rates). Decaying vegetation in such swampy waters provides large inputs of plant material

that consumes oxygen as it decays. The decaying vegetation in swamp water also produces acids and decreases pH. Plant materials contain polyphenols such as tannin and lignin. Polyphenols and partially degraded polyphenols build up in the form of tannic acids, humic acids, and fulvic acids that are highly colored. The trees of swamps have higher polyphenolic content than the soft-stemmed vegetation of marshes. Swamp streams (blackwater) are therefore more highly colored and more acidic than marsh streams.

Appearance and flow velocity (or slope if flow velocity is not available) must be identified for each stream or stream segment to be assessed for natural conditions and potential re-classification as Class VII swamp water. This can be done through maps, photos, field measurements or other appropriate means.

Step 2. Determine nutrient levels.

Excessive nutrients can cause a decrease in DO in relatively slow moving systems, where aeration is low. High nutrient levels are an indication of anthropogenic inputs of nitrogen, phosphorus, and possibly organic matter. Nutrient input can stimulate plant growth, and the resulting die-off and decay of excessive plankton or macrophytes can decrease DO levels.

USGS (1999) estimated national background nutrient concentrations in streams and groundwater from undeveloped areas. Average nitrate background concentrations are less than 0.6 mg/L for streams, average total nitrogen (TN) background concentrations are less than 1.0 mg/L, and average background concentrations of total phosphorus (TP) are less than 0.1 mg/L.

Nutrient levels must be documented for each stream or stream segment to be assessed for natural conditions and potential re-classification as Class VII swamp water. Streams with average concentrations of nutrients greater than the national background concentrations should be further evaluated for potential impacts from anthropogenic sources.

Step 3. Determine degree of seasonal fluctuation (for DO only).

Anthropogenic impacts on DO will likely disrupt the typical seasonal fluctuation seen in the DO concentrations of wetland streams. Seasonal analyses should be conducted for each potential Class VII stream or stream segment to verify that DO is depressed in the summer months and recovers during the winter, as would be expected in natural systems. A weak seasonal pattern could indicate that human inputs from point or nonpoint sources are impacting the seasonal cycle.

Step 4. Determine anthropogenic impacts.

Every effort should be made to identify human impacts that could exacerbate the naturally low DO and/or pH. For example, point sources should be identified and DMR data analyzed to determine if there is any impact on the stream DO or pH concentrations. Land use analysis can also be a valuable tool for identifying potential human impacts.

Lastly, a discussion of acid rain impacts should be included for low pH waters. The format of this discussion can be based either on the process used for the recent Class VII classification of several streams in the Blackwater watershed of the Chowan Basin (letter from DEQ to EPA, 14 October 2003). An alternative is a prototype regional stream comparison developed for Fourmile Creek, White Oak Swamp, Matadequin Creek and Mechumps Creek (all east of the fall line). The example analysis under IV in this document, or the example report prepared for Fourmile Creek, illustrate this approach. For streams west of the fall line, a regional stream comparison for 2004 analyses encompasses Winticomack, Winterpock, and Chickahominy Rivers.

7Q10 Data Screen

If the data warrant it, a data screen should be performed to ensure that the impairment was identified based on valid data. All DO or pH data that violate water quality standards should be screened for flows less than the 7Q10. Data collected on days when flow was < 7Q10 should be eliminated from the data set and the violation rate recalculated accordingly. Only those waters with violation rates determined days with flows > or = 7Q10 flows should be classified as impaired.

In some cases, data were collected when flow was 0 cfs. If the 7Q10 is identified as 0 cfs as well, all data collected under 0 cfs flow would need to be considered in the water quality assessment. In those cases, the impairment should be classified as 4C, impaired due to natural conditions, no TMDL needed. However, a reclassification to Class VII may not always be appropriate.

III. NATURAL CONDITION CONCLUSION MATRIX

The following decision process should be applied for determining whether low pH and/or low DO values are due to natural conditions and justify a reclassification of a stream or stream segment as Class VII, Swamp Water.

If velocity is low or if slope is low (<0.50%) AND
If wetlands are present along stream reach AND
If no point sources or only point sources with minimal impact on DO and pH AND
If nutrients are < typical background

- ❖ average (= assessment period mean) nitrate less than 0.6 mg/L
- ❖ average total nitrogen (TN) less than 1.0 mg/L, and
- ❖ average total phosphorus (TP) are less than 0.1 mg/L AND

For DO: If seasonal fluctuation is normal AND
For pH: If nearby streams without wetlands meet pH criteria OR if no correlation between in-stream pH and rain pH,

THEN determine as impaired due to natural condition
→ assess as category 4C in next assessment
→ initiate WQS reclassification to Class VII Swamp Water
→ get credit under consent decree

The analysis must state the extent of the natural condition based on the criteria outlined above. A map showing land use, point sources, water quality stations and, if necessary, the delineated segment to be classified as swamp water should be included.

In cases where not all of these criteria apply, a case by case argument must be made based on the specific conditions in the watershed.

5.1 Preliminary Data Screen for Low Flow 7Q10

The 7Q10 flow of a stream is the lowest streamflow for seven consecutive days that occurs on average once every ten years. The first step for low flow 7Q10 screening is to determine the most accurate 7Q10 available. The 7Q10 flow for Beaverdam Creek may be estimated by a drainage area ratio of the Beaverdam Creek watershed (7.37 mi^2) with the 7Q10 flow at the long-term continuous gaging station Piscataway Creek near Tappahannock, VA, (USGS:01669000), with a drainage area of 28.0 mi^2 and a 7Q10 of 0.50 cfs (2005). Thus the 7Q10 of Beaverdam Creek is estimated at 0.13 cfs.

The DO Instantaneous Water Quality Standard applies **AT** 7Q10 flow, but **NOT** below 7Q10 flow (9 VAC 25-260-50 ***). Therefore in streams where the 7Q10 > 0.0 cfs, DO less than 4.0 mg/l taken at flows below 7Q10 are not water quality standard violations. However, in streams where the 7Q10 = 0.0 cfs, **ALL** DO data < 4.0 mg/l are standard violations, even if the flow = 0 cfs when the DO was taken.

No Beaverdam Creek and tributaries DO or pH water quality data, standard violations or non-violations were obtained at flows below 7Q10, therefore no data were removed.

5.2 Low slope, Swamps, Wetlands or Large Forested Areas

The percent slope of Beaverdam Creek and tributaries ranged from 0.17% to 0.26% slope (Table 5). This is lower than the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swamps and heavy tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic impacts.

Table 5. Calculated percent slopes for Beaverdam Creek and tributaries.

Stream	% Slope	Upstream Elevation (Feet) at Rivermile (RM)	Downstream Elevation (Feet) at Rivermile (RM)
Beaverdam Creek	0.17	60’ at RM 6.47	30’ at RM 3.08
UT to Beaverdam Creek (XAH)	0.26	60’ at RM 1.97	40’ at RM 0.50

Visual inspection of Beaverdam Creek and tributaries revealed large open swampy areas and heavy tree canopy in other swamp segments. Decomposition of vegetative matter from large swampy areas lowers DO and pH as decay occurs. (Figures 14 - 16).

Figure 14. Beaverdam Creek, 2-BDM004.12, Rt. 632, Upstream.

Figure 15. Beaverdam Creek, 2-BDM004.60, Rt. 33, Upstream.

Figure 16. UT to Beaverdam Creek 300 m Southeast of Rt. 33, Upstream.

5.3 Instream Nutrients

The VADEQ collected nutrient data from the original listing station 2-BDM004.12 (June 1996 to June 2009, Table 7). The average nitrate and total nitrogen concentrations are below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas with levels of nitrate < 0.6 mg/l and TN < 1.0 mg/l. These low nutrient levels are not indicative of human impact. The average total phosphorus (TP) of 0.128 mg/l was moderately higher than the USGS (1999) background TP value of 0.1 mg/l. The nitrogen levels were all low, however both TP and orthophosphate (o-P) the somewhat higher than normal background levels. There are no permitted dischargers in the Beaverdam Creek watershed. However there is an unpermitted mulch facility upstream of station 2-BDM004.60 and below 2-BDM005.70, which will be discussed in Section 5.5 below. Because of the elevated TP at the listing station, DEQ monitored nutrients at the 3 other stations in 2009. Those data are shown in Tables 8 – 10.

Table 7. Instream Nutrients of Beaverdam Creek 2-BDM004.12.

Parameter	Average Conc.	Number
Total Phosphorus	**0.128 mg/l**	(n=45) (28% above USGS 0.1 mg/L background)
Orthophosphorus	0.082 mg/l	(n=35)
Total Kjeldahl Nitrogen	0.663 mg/l	(n=35)
Ammonia as N	0.055 mg/l	(n=41)
Nitrate as N	**0.026 mg/l**	(n=35)
Nitrite as N	0.008 mg/l	(n=35)
TN (TKN + NO_3 + NO_2)	**0.677 mg/l**	(n=45)
Nitrite + Nitrate, Total as N	0.032 mg/l	(n=41)

Table 8. Instream Nutrients of Beaverdam Creek 2-BDM004.60.

Parameter	Average Conc.	Number
Total Phosphorus	**0.189 mg/l**	(n=10) (89% above USGS 0.1 mg/L background)
Orthophosphorus	0.143 mg/l	(n=10)
Total Kjeldahl Nitrogen	0.830 mg/l	(n=10)
Ammonia as N	0.046 mg/l	(n=10)
Nitrate as N	**0.020 mg/l**	(n=10)
Nitrite as N	0.009 mg/l	(n=10)
TN (TKN + NO_3 + NO_2)	**0.859 mg/l**	(n=10)
Nitrite + Nitrate, Total as N	0.029 mg/l	(n=10)

The TP levels at this station between the listing station and the mulch facility were higher than at the listing station, however there is another unmonitored UT also entering Beaverdam Creek between this station and the mulch facility.

Table 9. Instream Nutrients of Beaverdam Creek 2-BDM005.70.

Parameter	Average Conc.	Number
Total Phosphorus	**0.109 mg/l**	(n=10) (9% above USGS 0.1 mg/L background)
Orthophosphorus	0.061 mg/l	(n=10)
Total Kjeldahl Nitrogen	0.790 mg/l	(n=10)
Ammonia as N	0.034 mg/l	(n=10)
Nitrate as N	**0.021 mg/l**	(n=10)
Nitrite as N	0.009 mg/l	(n=10)
TN (TKN + NO_3 + NO_2)	**0.821 mg/l**	(n=10)
Nitrite + Nitrate, Total as N	0.031 mg/l	(n=10)

This station is upstream of the mulch facility and the other UT to Beaverdam Creek. The TP at this site barely exceeds the background TP level, and is 42 percent lower than the station downstream.

Table 10. Instream Nutrients of UT to Beaverdam Creek 2CXAH000.35.

Parameter	Average Conc.	Number
Total Phosphorus	**0.103 mg/l**	(n=7) (3% above USGS 0.1 mg/L background)
Orthophosphorus	0.056 mg/l	(n=7)
Total Kjeldahl Nitrogen	0.857 mg/l	(n=7)
Ammonia as N	0.023 mg/l	(n=7)
Nitrate as N	**0.019 mg/l**	(n=7)
Nitrite as N	0.009 mg/l	(n=7)
TN (TKN + NO_3 + NO_2)	**0.885 mg/l**	(n=7)
Nitrite + Nitrate, Total as N	0.027 mg/l	(n=7)

This station is on a UT that enters Beaverdam Creek downstream of both the mulch facility and TP-elevated station 2-BDM004.60. It also enters Beaverdam Creek above original station 2-BDM004.12. The TP at this site is also just over the TP background level and is similar to TP at the upstream background Beaverdam Creek station 2-BDM005.70. The lower TP concentration at this station seemed to dilute those from station 2-BDM004.60 at Rt. 30.

It is unusual that only TP levels are elevated in this watershed while nitrogen species are not high. This would seem to point to a natural source of TP, perhaps in the geology, rather than a point source such as a mulch facility or agriculture, which would also contribute excess nitrogen. There are no acres of pasture and only 38 acres of cropland in the watershed (Table 2), so agricultural runoff is not a likely source of the elevated TP either. Nevertheless, with the elevated TP, Beaverdam Creek should not be designated Class VII swampwaters as the nutrient criteria for designation exist now.

5.3.1 Utility of nutrient restrictions for Class VII designation.

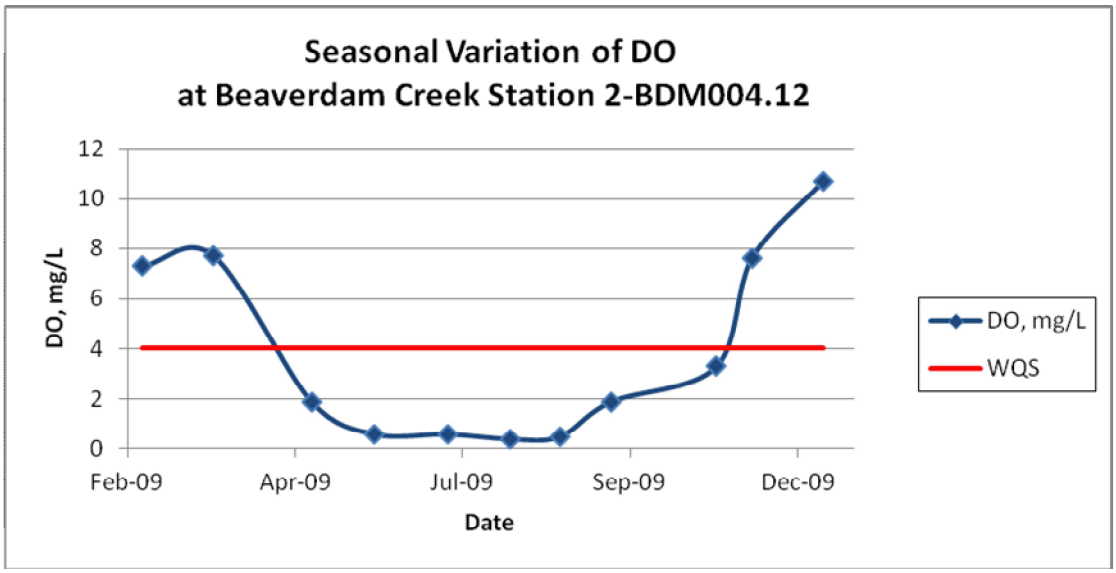
The argument can be made that even though TP is elevated above the USGS background levels, Beaverdam Creek, or any potential swampwater designee, is still a swamp, with naturally low pH and/or DO, albeit one with slightly to moderately elevated TP. As long as slope percentage is below 0.50%, swampwater characteristics are present, and anthropogenic point sources are not present which contribute acidic effluents to lower pH or high BOD effluents to lower DO, a swamp will still naturally have low dissolved oxygen and low pH. Non-point source (NPS) TP or TN rarely if ever cause low DO or pH problems by themselves because they are not nutrient-rich enough, absent a point source of biochemical or chemical oxygen demand or a rare illicit dumping of concentrated TN source like fertilizer.

The effect of a Class VII designation is to lower the pH and DO water quality standards to pH 4.3 and to a narrative low DO standard, so that natural swampwaters with low DO and pH do not require an unnecessary Total Maximum Daily Load clean-up study where there is nothing to clean up. This standards relief is needed and appropriate for a natural swamp segment whether or not nutrient species are somewhat elevated.

5.4 Natural Seasonal DO Fluctuation

The 2009 DO data collected at the Beaverdam Creek original listing station 2-BDM004.12 were graphed to demonstrate the natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO. There was no January 2009 sample because of repeated snow and icy conditions. DO is high in the winter months while water temperatures are low, and low in the summer months when water temperatures are high. This is depicted in Figure 17.

Figure 17. Seasonal DO Variation at Beaverdam Creek at Rt. 632, February to December 2009.



5.5 Impact from Point Source Dischargers and Land Use

There are no active permitted point source dischargers in the Beaverdam Creek watershed. However there is an unpermitted mulch facility upstream of station 2-BDM004.60 and below 2-BDM005.70.

The watershed is approximately 4723 acres (7.37 mi^2) in size and is predominately forested (68 percent). Agriculture (cropland) comprises only 1 percent of the watershed, with no significant pasture/hayland. Urban

areas compose approximately 10 percent of the land base. The remaining 21 percent of the watershed is comprised of 12 percent other grasses and 9 percent wetlands. Land use was not considered to have significantly impacted the swampwater conditions of Beaverdam Creek and tributaries.

6. CONCLUSION

The following decision process is proposed for determining whether low DO values are due to natural conditions:

If slope is low (<0.50) AND
If wetlands or large areas of forested land are present along stream reach AND
If no point sources or point sources with minimal impact on DO AND
If nutrients are < typical background
- ❖ average (= assessment period mean) nitrate less than 0.6 mg/L
- ❖ average total nitrogen (TN) less than 1.0 mg/L, and
- ❖ average total phosphorus (TP) are equal to or less than 0.1 mg/L AND

If nearby streams without wetlands meet DO criteria,

THEN determine as impaired due to natural condition
→ assess as category 4C in next assessment
→ initiate WQS reclassification to Class VII Swamp Water
→ get credit under consent decree

No Beaverdam Creek and tributaries DO or pH water quality data, standard violations or non-violations were obtained at flows below 7Q10, therefore no data were removed.

The percent slope of Beaverdam Creek and tributaries ranged from 0.17% to 0.26% slope (Table 5). This is lower than the defined low slope criteria of 0.50%. Decomposition of the large inputs of decaying vegetation from areas of forested land with swamps and heavy tree canopy throughout the watersheds increase oxygen demand and lower DO as they decay, as well as contribute to the low pH by creation of natural weak organic acids (tannic, humic and fulvic acids) during decomposition of the decaying vegetation. These are not considered anthropogenic impacts.

The VADEQ collected nutrient data from the original listing station 2-BDM004.12. The average nitrate and total nitrogen concentrations are below the USGS (1999) national background nutrient concentrations in streams from undeveloped areas with levels of nitrate < 0.6 mg/l and TN < 1.0 mg/l. These low nutrient levels are not indicative of human impact. The average total phosphorus (TP) of 0.128 mg/l was moderately higher (28%) than the USGS (1999) background TP value of 0.1 mg/l. The nitrogen levels were all low, however both TP and orthophosphate (o-P) the somewhat higher than normal background levels. There are no permitted dischargers in the Beaverdam Creek watershed. However there is an unpermitted mulch facility upstream of station 2-BDM004.60 and below 2-BDM005.70. Because of the elevated TP at the listing station, DEQ monitored nutrients at the 3 other stations in 2009. The TP levels at station 2-BDM004.60 between the listing station and the mulch facility were 89% above the USGS background, and were higher than at the listing station, however there is another unmonitored UT also entering Beaverdam Creek between this station and the mulch facility. Station 2-BDM005.70 is upstream of the mulch facility and the other unmonitored UT to Beaverdam Creek. The TP at this site barely exceeded (3% higher) the background TP level, and is 42 percent lower than the station downstream. Station 2CXAH000.35 is on a UT that enters Beaverdam Creek downstream of both the mulch facility and TP-elevated station 2-BDM004.60, and upstream of the original station 2-BDM004.12. The TP at this site was also just over (9% higher) the TP background level and is similar to TP at the upstream background Beaverdam Creek station 2-BDM005.70. The lower TP concentration at this UT station seemed to dilute those from station 2-BDM004.60 at Rt. 30.

It is unusual that only TP levels are elevated in this watershed while nitrogen species are not high. This would seem to point to a natural source of TP, perhaps in the geology, rather than a point source such as a mulch facility or agriculture, which would also contribute excess nitrogen. There are no acres of pasture and only 38 acres of cropland in the watershed, so agricultural runoff is not a likely source of the elevated TP

either. Nevertheless, with the elevated TP, Beaverdam Creek should not be designated Class VII swampwaters as the nutrient criteria for designation exist now.

Beaverdam Creek exhibits natural seasonal DO fluctuation due to the inverse relationship between water temperature and DO.

There are no active permitted point source dischargers in the Beaverdam Creek watershed. However there is an unpermitted mulch facility upstream of station 2-BDM004.60 and below 2-BDM005.70. DEQ will seek permission to sample for nutrients immediately above and below this facility to determine whether it is a source of elevated TP.

The watershed is approximately 4723 acres (7.37 mi^2) in size and is predominately forested (68 percent). Agriculture (cropland) comprises 1 percent of the watershed, with no significant pasture/hayland. Urban areas compose approximately 10 percent of the land base. The remaining 21 percent of the watershed is comprised of 12 percent other grasses and 9 percent wetlands.

Based on the above information, a change in the water quality standards classification to Class VII Swampwater due to natural conditions, rather than a TMDL, is NOT indicated for Beaverdam Creek and tributaries located in waterbody identification codes (WBID) VAP-F12R because the TP concentrations at the four monitoring stations were from 3% and 89% greater than the nutrient concentrations deemed by the USGS to indicate background nutrient levels. Beaverdam Creek in VAP-F12R will receive a non-point source (NPS) load allocation for TP and TN in the approved Chesapeake Bay TMDL. This will obviate the need for a future nutrient-based DO and pH TMDL for the watershed.

The argument may be made that even though TP is elevated above the USGS background levels, Beaverdam Creek, or any potential swampwater designee, is still a swamp, with naturally low pH and/or DO, albeit one with slightly to moderately elevated TP. As long as slope percentage is below 0.50%, swampwater characteristics are present, and anthropogenic point sources are not present which contribute acidic effluents to lower pH or high BOD effluents to lower DO, a swamp will still naturally have low dissolved oxygen and low pH. NPS TP or TN rarely if ever cause low DO or pH problems by themselves because they are not nutrient-rich enough, absent a point source of biochemical or chemical oxygen demand or a rare illicit dumping of concentrated TN source like fertilizer. The effect of a Class VII designation is to lower the pH and DO water quality standards to pH 4.3 and to a narrative low DO standard, so that natural swampwaters with low DO and pH do not require an unnecessary Total Maximum Daily Load clean-up study where there is nothing to clean up. This standards relief is needed and appropriate for a natural swamp segment whether or not nutrient species are somewhat elevated.

DEQ performed the assessment of the Beaverdam Creek and tributaries low DO and low pH natural condition in lieu of a TMDL. Therefore neither a TMDL Technical Advisory Committee (TAC) meeting nor a public meeting was involved. Public participation will occur during the next water quality standards triennial review process.

7. References

Maptech, Methodology for Assessing Natural Dissolved Oxygen and pH Impairments: Application to the Appomattox River Watershed, Virginia. 2003.

NRCS (Natural Resource Conservation Service) http://soils.usda.gov/technical/classification/osd/index.html (Accessed 09/04/2008)

SRCC (Southeast Regional Climate Center) http://www.dnr.state.sc.us/climate/sercc/products/historical/historical_va.html (Accessed 12/18/02)

USGS (United States Geological Survey), National Background Nutrient Concentrations in Streams from Undeveloped Areas. 1999.

VADCR (Virginia Department of Conservation and recreation) http://www.dcr.virginia.gov/natural_heritage/documents/overviewPhysiography_vegetation.pdf (Accessed 09/04/2008)

VADEQ (Virginia Department of Environmental Quality), Virginia Water Quality Assessment 1998. Virginia. 1998.

VADEQ (Virginia Department of Environmental Quality), Virginia Water Quality Assessment 2002. Virginia. 2002.

VADEQ (Virginia Department of Environmental Quality), Virginia Water Quality Assessment 2008. Virginia. 2008.

VADEQ (Virginia Department of Environmental Quality), Virginia Integrated Report 2010. Virginia. 2010.

VADEQ (Virginia Department of Environmental Quality), Virginia Integrated Report 2012. Draft. Virginia. 2012.